(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 235 062 A1

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
28.08.2002 Bulletin 2002/35

(51) Int Cl.[7]: **G01M 11/00**

(21) Application number: **01128563.2**

(22) Date of filing: **30.11.2001**

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE TR
Designated Extension States:
AL LT LV MK RO SI

(71) Applicant: **Agilent Technologies, Inc. (a Delaware corporation)**
Palo Alto, CA 94303 (US)

(72) Inventor: **Stadler, Dietmar**
71034 Breitenstein (DE)

(74) Representative: **Barth, Daniel Mathias et al**
Agilent Technologies Deutschland GmbH
Patentabteilung
Herrenberger Strasse 130
71034 Böblingen (DE)

(54) Measurement of multi-port optical devices

(57) An optical device under test - DUT - (10) having m inputs, with m = 1, 2, 3, ..., M, and n outputs, with n = 1, 2, 3, ..., N, is tested by applying a plurality of different characteristic stimulus signals (Si) to at least one of the m inputs. A response signal (Ri) is received at at least one of the n outputs, and a property of the DUT (10) can be determined or verified by evaluating the received response signal in conjunction with at least one of the applied stimulus signals (Si) or at least an indication thereof. The plurality of different characteristic stimulus signals (Si) are provided in a way allowing tracing each respectively applied stimulus signal (Si) in each received response signal (Ri) - if present or beyond a detectability threshold.

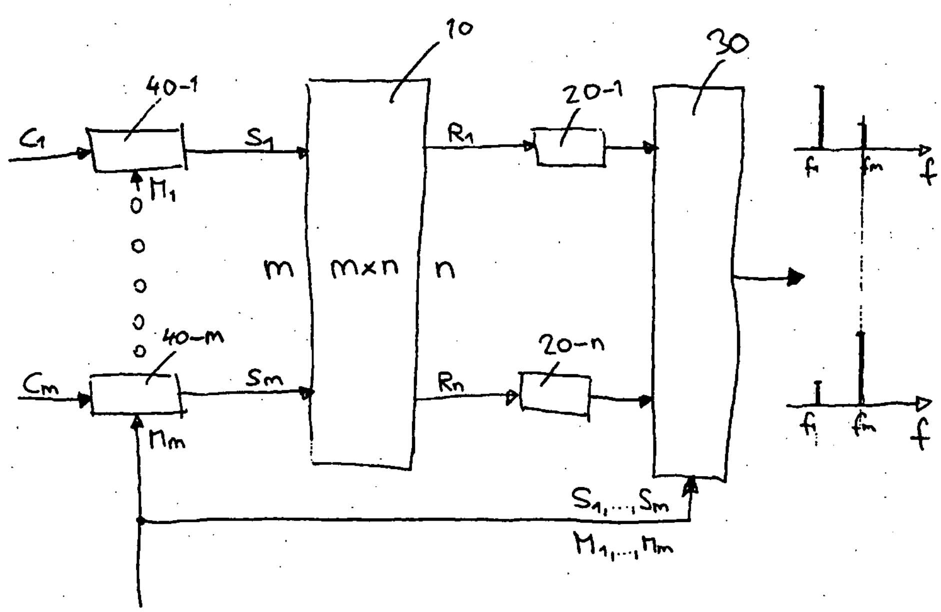

Fig. 1

EP 1 235 062 A1

Printed by Jouve, 75001 PARIS (FR)

Description

BACKGROUND OF THE INVENTION

[0001] The present invention relates to the measurement of multi-port optical devices such as switches, cross-connects, etc.

[0002] Testing optical multi-port devices such as cross-connects for connecting a plurality of outputs with a plurality of inputs has become an increasingly important task for modern optical telecommunication industry. Since such multi-port devices offer a wide variety of different connection options, testing or verifying each option and also measuring optical properties or unwanted side effects can become extremely time intensive. Considering e.g. an nxn-cross connect (with n inputs and n outputs), each of the 2^n or even n! switch possibilities should be tested.

SUMMARY OF THE INVENTION

[0003] It is an object of the present invention to provide an improved testing for multi-port optical devices. The object is solved by the independent claims. Preferred embodiments are shown by the dependent claims.

[0004] According to the present invention, an optical device under test (DUT) having m inputs (with m = 1, 2, 3, ..., M) and n outputs (with n = 1, 2, 3, ..., N) is tested by applying a plurality of different characteristic stimulus signals to at least one of the m inputs. A response signal received at at least one of the n outputs is provided to an evaluation unit together with the applied stimulus signals or at least an indication thereof. The evaluation unit determines from the received response signals and the stimulus indication a property of the DUT, such as an optical property (e.g. in insertion loss, crosstalk, or isolation) or a verification of a device property (e.g. a connection between different paths or input and outputs, a switch matrix, etc.).

[0005] The stimulus signals have to be provided in a way allowing tracing each respectively applied stimulus signal in a received response signal - if present e.g. beyond detectability thresholds. The term tracing shall mean identifying at least a portion of the applied stimulus signal in a received response signal, and might also covering a quantitative analysis of the identified portion with respect to the applied stimulus signal.

[0006] The term indication of an applied stimulus signal shall mean any kind of representative information rendering possible to trace this stimulus signal in the response signal.

[0007] Preferably, each stimulus signal provides a unique feature allowing to unambiguously identify each stimulus signal - or parts thereof - in each received response signal. This capability of tracing portions of each applied characteristics stimulus signal in each of the received response signals allows to apply multiple stimulus signals concurrently or at least substantially concurrently, thus allowing significantly reduced testing time.

[0008] In one embodiment each stimulus signal comprises a carrier portion and an identification portion. At least one of the carrier portion or the identification portion comprises a unique feature allowing to unambiguously identify each stimulus signal - or parts thereof - in each received response signal. In one embodiment, the carrier portion is the same, or substantially the same, for all or some of the applied stimulus signals, however, varying carrier portions might be applied as well. The unique portions have to be selected in a way that they can be clearly and unambiguously traced in the response signal(s). In other words, the tracing or identification scheme provided for evaluating the response signal(s) has to be adapted to the type of identification as applied for in the identification portions.

[0009] Whereas substantially any adequate identification scheme for providing the unique identification portion can be applied, it has been found that in particular modulation (e.g. intensity, amplitude, phase, or frequency modulation) can provide a very effective tracing, in particular suitable when detecting the response signal (s) with standard power meters providing sensibility mainly with respect to applied optical power. However, other identification schemes such as coding (e.g. with unique data content) etc. can be applied as well.

[0010] While the carrier portion of the stimulus signals might be substantially the same and even be derived from the same source, same applications might require different carrier portions. In particular in case the DUT provides different paths (e.g. transmission paths) for different wavelengths, different carrier portions at different wavelengths can be applied.

[0011] In a preferred embodiment wherein the DUT comprises at least two inputs, two or more (and preferably all) of the inputs each receives a different stimulus signal having a common carrier portion but a unique identification portion.

[0012] In another preferred embodiment wherein the DUT has at least one carrier sensitive input (e.g. the behavior of the DUT depends on the applied carrier portion), the carrier sensitive input will receive at least two different stimulus signals, each having a different carrier portion and/or a different unique identification portion. In an example with a DUT having different transmission paths for different wavelengths, each carrier portion concurrently applied comprises a carrier portion at a different wavelength.

[0013] In one embodiment, the carrier of a plurality of stimulus signals comprises a plurality of different carrier portions, but each applied stimulus signals has a different unique identification portion. This can be achieved e.g. by applying a broadband source already providing the plurality of different carrier portions.

[0014] In one preferred embodiment, the unique identification portion of each stimulus signal is provided by applying a modulation scheme as known in the art. Pref-

erably, an amplitude modulation is provided by modulating a carrier signal representing the carrier portion. The amplitude modulation can be provided by modulating the intensity of the carrier signal. The response signals can be detected employing conventional power meters (e.g. with photo diodes) for converting the received optical signals into electrical signals. The evaluation unit can apply various evaluation methods as known in the art for tracing unique identification portions, or parts thereof, in each received response signal. Thus and with the knowledge about each different stimulus signal and their distribution to the DUT input(s), the evaluation unit can determine the requested property of the DUT (e.g. as insertion loss of the each transmission path, crosstalk or isolation between different transmission paths, or verification of a connection scheme (expected or unexpected) between inputs and outputs.

[0015] Preferred examples of evaluation methods in time domain are synchronous demodulation, correlation, regression algorithms (e.g. 3 parameter fit). Preprocessing methods like transfer on intermediate frequency (ZF) or filter banks can be applied in addition or alternatively. In frequency domain, e.g. Fourier transformation (e.g. Fast Fourier Transformation - FFT) or correlation can be applied. However, it is clear that other or multiple evaluation methods can be applied accordingly.

[0016] Amplitude modulation is in particular useful since the conversion from optical to electrical signals as provided by most commonly available detectors (e.g. photodiodes) is generally very sensitive to variations in the intensity but normally less sensitive to wavelength variations in the optical signal.

[0017] In a preferred embodiment applying amplitude modulation, the modulation frequency range preferably covers the sub-ultrasonic range, preferably in the range of smaller than 100MHz. However, the application of modulation frequency ranges is generally only limited by the bandwidth of involved components. When applying state of the art technology, the most limiting factor will be the device for measuring light intensity with a given input bandwidth (e.g. the photo diode). The maximum modulation frequency is therefor limited generally to Fmax <= Fs/4, where Fs is the sampling rate of the power values, Fmax is the highest preferred modulation frequency. The input bandwidth of an employed powermeter is generally roughly in the range of Fs/4.

[0018] The at least two different characteristic stimulus signals are preferably applied in parallel, e.g. concurrently or at least substantially concurrently (i.e. within a short period of time). It is to be understood the provision of stimulus signals according to the invention which are independently traceable within each received response signal allows to provide such stimulus signals in parallel. This allows to significantly reduce testing time in particular when testing mxn devices with high number of inputs and/or outputs or when the device provides a high number of possible connections to be tested. It is clear, however, that the stimulus signals can also be provided sequentially or in a pseudo parallel mode.

[0019] The invention has found to be in particular useful for testing optical multi-port devices such as optical cross connectors, optical switches, or switch fabrics, in particular when reaching a high number of inputs and/or outputs. In case of a switch with m inputs and n outputs, wherein a transmission path between one input and one output can either be closed or opened, one measurement with concurrently applying different stimulus signals at each of the m inputs and all transmission paths being connected will generally be sufficient e.g. for providing loss or crosstalk measurements of the entire switch. In case of an optical cross connect for routing each one of m inputs to a selectable one of n outputs, providing m measurements will generally be sufficient accordingly. However, it is clear that any mxn multi-port device can be tested using the invention.

[0020] It is clear that the invention can be partly or entirely embodied or supported by one or more suitable software programs, which can be stored on or otherwise provided by any kind of data carrier, and which might be executed in or by any suitable data processing unit. Software programs or routines are preferably applied for controlling the application and/or provision of the stimulus signals (e.g. controlling one or more signal sources and/or modulation units), or for evaluating the response signals (e.g. by the evaluation unit).

BRIEF DESCRIPTION OF THE DRAWINGS

[0021] Other objects and many of the attendant advantages of the present invention will be readily appreciated and become better understood by reference to the following detailed description when considering in connection with the accompanied drawings. Features that are substantially or functionally equal or similar will be referred to with the same reference sign(s).

[0022] Figure 1 illustrates a preferred embodiment of the present invention. Figure 2 depicts a fast method for testing an optical switch fabric, and Figs. 3 illustrates other testing schemes.

DETAILED DESCRIPTION OF THE INVENTION

[0023] In Figure 1, a device under test (DUT) 10 with m inputs and n outputs is to be tested (with m, n = 1, 2, 3, ..., N). Each of the m inputs receives a different and characteristic stimulus signal S_i (with i = 1, 2, 3, ..., m) and each of the n outputs provides a response signal R_j (with j= 1, 2, 3, ... n). Each response signal R_j is received by a respective detector 20-j, and the detected response signals are provided to an evaluation unit 30. The evaluation unit 30 further receives each stimulus signal S_i, or at least an indication of each stimulus signal S_i allowing to unambiguously identifying each applied stimulus signal S_i (or a corresponding portion thereof) in the response signals R_j.

[0024] In operation, all stimulus signals S_i are applied

in parallel (preferably concurrently) to the DUT 10, and the resulting response signals R_j are detected by each respective detector 20-j and provided to the evaluation unit 30. Making use of the knowledge about the unique character of each stimulus signal S_i, the evaluation unit 30 will evaluate the response signals R_j in order to derive at least one optical property of the DUT 10. Such optical properties can be - for example - insertion loss, crosstalk, isolation, or a verification of an expected transmission path between input and output.

[0025] In a preferred embodiment, each stimulus signal S_i is provided by a respective modulation unit 40-i. Each modulation unit 40-i receives a carrier signal C_i and a modulation signal M_i and provides therefrom the stimulus signal S_i.

[0026] In a preferred embodiment, each modulation unit 40-i provides an amplitude modulation for modulating the light intensity of the applied carrier signal C_i. In this embodiment, the carrier signals C_i can all be the same or at least substantially the same and might even be derived from the same source. In that case, it can be sufficient to provide only the modulation signals M_i, or a corresponding indication or representation thereof such as a modulation frequency f_i, as indication for each unique stimulus signal S_i.

[0027] In the embodiment applying amplitude modulation, the detectors 20-j can be embodied e.g. by conventional photodiodes. The evaluation unit 30 will then detect frequency portions f_i in each one of the response signals R_j. The right side of Figure 1 illustrates an example with detected frequency portions f_1 and f_m resulting from the stimulus signals S_1 and S_m Dependent on the application, the evaluation unit 30 might determine insertion loss, isolation or crosstalk by processing the intensities of the received frequency portions in combination with each other. Such processing is well known in the art and need not be explained herein in detail. Typical algorithms can be correlation or Fourier transformation (e.g. using Fast Fourier Transformation) in frequency domain, or e.g. synchronous demodulation, correlation, regression algorithms like 3 parameter fit (they could additionally be combined with preprocessing methods like transfer on intermediate frequency (ZF) or filter banks).

[0028] A preferred embodiment for testing a switch fabric 100 is depicted with respect to Figure 2 representing a generic model in particular for so-called 3D Mems. The optical switch fabric 100 in this embodiment shall have four inputs I_1, I_2, I_3, and I_4 and four outputs O_1, O_2, O_3 or O_4. It is clear, however, that the number of inputs and outputs is not limited. Each one of the inputs can be connected to either one of the outputs. A potential connection e.g. between input I_1 and output O_1 is indicated in Figure 2 by a switch 110. It goes without saying that any other connection can be provided accordingly.

[0029] For testing the switch fabric 100, four measurements each with concurrently applying different characteristic stimulus signals S_1-S_4 to the inputs I_1 - I_4 are provided. The corresponding response signals R_1 - R_4 are measured at the outputs O_1 - O_4. Each measurement preferably measures one line of the matrix connection structure of the switch fabric 100. This explains the number of four measurements in the 4x4-switch fabric example of Figure 2. Accordingly an mxm switch fabric requires at least m measurements.

[0030] Figure 3A illustrates the principles for testing a multiplexing or demultiplexing device 200. Whether the device 200 is provided as multiplexer or demultiplexer depends on the direction for operating the device 200, or in other words whether signals (in Fig. 3A) are applied from the left (multiplexer) or the right (demultiplexer) side.

[0031] In its multiplexing mode, the device 200 has one input but n outputs. A signal applied at the input (left side) of the device 200 will be provided to one or more of its n outputs (right side) dependent on its configuration and the wavelength(s) of the input signal. For testing the device 200 a plurality of stimulus signals, each with different wavelength of the carrier signal and a different unique identification portion, will be concurrently provided to the its input. The response signals R_j are detected and analyzed in accordance with the above said. For testing the device 200 in its multiplexing mode, the stimulus signal S_j are provided from the right side in Figure 3A and the signal responses R_j are detected at the left side of the device 200.

[0032] The same principles as illustrated with respect to Figure 3A for testing the multiplexing / demultiplexing device 200 can also be applied for testing an optical cross connect as shown in Fig. 3B. The optical cross connect comprises a 1xm multiplexing device 200 for multiplexing one input to m outputs, an mxn switch fabric 100 for switching m inputs to n outputs, and an nx1 demultiplexing device 200 for demultiplexing n inputs to 1 output.

Claims

1. A system adapted for determining or verifying a property of an optical device under test - DUT - (10) having m inputs, with m = 1, 2, 3, ... M, and n outputs, with n = 1, 2, 3, ..., N, wherein a plurality of different characteristic stimulus signals (Si) are applied to at least one of the m inputs, the system comprising:

   a signal receiving unit (20) adapted for receiving a response signal (Ri) at at least one of the n outputs, and

   an evaluation unit (30) adapted for determining or verifying the property of the DUT (10) by evaluating the received response signal in conjunction with at least one of the applied stimulus signals (Si) or at least an indication thereof.

2. The system of claim 1, wherein the evaluation unit (30) is adapted for identifying at least a portion of the applied stimulus signal in each received response signal.

3. The system of claim 2, wherein the evaluation unit (30) is adapted for providing a quantitative analysis of the identified portion with respect to the applied stimulus signal.

4. A system adapted for testing an optical device under test - DUT - (10) having m inputs, with m = 1, 2, 3, ..., M, and n outputs, with n = 1, 2, 3, ..., N, the system comprising:

   a signal application unit (40) adapted for applying a plurality of different characteristic stimulus signals (Si) to at least one of the m inputs,

   the system of claim 1 or any one of the claims 2-3 for determining or verifying a property of the DUT (10).

5. The system of claim 4, wherein the signal application unit (40) is adapted for applying the plurality of different characteristic stimulus signals (Si) in a way allowing tracing each respectively applied stimulus signal (Si) in each received response signal (Ri) - if present or beyond a detectability threshold.

6. The system of claim 4 or 5, wherein the signal application unit (40) is adapted for applying a plurality of different characteristic stimulus signals (Si) each having a unique feature allowing to unambiguously identify each stimulus signal - or parts thereof - in each received response signal.

7. The system of claim 4 or any one of the claims 5-6, wherein the signal application unit (40) is adapted for applying a plurality of different characteristic stimulus signals (Si) each having a carrier portion and/or an identification portion, with at least one of the carrier portion or the identification portion comprising a unique feature allowing to unambiguously identify each stimulus signal - or parts thereof - in each received response signal.

8. The system of claim 1 or any one of the claims 5-7, wherein the signal application unit (40) is adapted for providing a modulation or coding for generating the plurality of different characteristic stimulus signals (Si).

9. The system of claim 1 or any one of the claims 5-8, wherein the signal application unit (40) is adapted for providing at least some of the plurality of different characteristic stimulus signals (Si) in parallel, preferably concurrently or at least substantially concurrently.

10. A signal application unit (40) adapted for applying a plurality of different characteristic optical stimulus signals (Si) to at least one input of an optical device under test - DUT - (10) having m inputs, with m = 1, 2, 3, ... M, and n outputs, with n = 1, 2, 3,..., N.

11. The signal application unit (40) of claim 10 being adapted for applying a plurality of different characteristic stimulus signals (Si) each having a unique feature allowing to unambiguously identify each stimulus signal.

12. The signal application unit (40) of claim 10 or 11 being adapted for applying a plurality of different characteristic stimulus signals (Si) each having a carrier portion and/or an identification portion, with at least one of the carrier portion or the identification portion comprising a unique feature allowing to unambiguously identify each stimulus signal - or parts thereof - in each received response signal.

13. The signal application unit (40) of claim 10 or any one of the claims 11-12, comprising a unit for providing a modulation or coding for generating the plurality of different characteristic stimulus signals (Si).

14. The signal application unit (40) of claim 10 or any one of the claims 11-13, being adapted for providing at least some of the plurality of different characteristic stimulus signals (Si) in parallel, preferably concurrently or at least substantially concurrently.

15. A system adapted for testing an optical device under test - DUT - (10) having m inputs, with m = 1, 2, 3, ... M, and n outputs, with n = 1, 2, 3, ..., N, the system comprising:

   a signal application unit (40) adapted for applying a plurality of different characteristic stimulus signals (Si) to at least one of the m inputs,

   a signal receiving unit (20) adapted for receiving a response signal (Ri) at at least one of the n outputs, and

   an evaluation unit (30) adapted for determining or verifying a property of the DUT (10) by evaluating the received response signal in conjunction with at least one of the applied stimulus signals (Si) or at least an

   indication thereof.

16. The system of claim 15, wherein the signal application unit (40) is adapted for applying the plurality of different characteristic stimulus signals (Si) in a way

allowing tracing each respectively applied stimulus signal (Si) in each received response signal (Ri) - if present or beyond a detectability threshold.

17. The system of claim 15 or 16, wherein the evaluation unit (30) is adapted for identifying at least a portion of the applied stimulus signal in each received response signal.

18. The system of claim 16, wherein the evaluation unit (30) is adapted for providing a quantitative analysis of the identified portion with respect to the applied stimulus signal.

19. The system of claim 15 or any one of the claims 16-18, wherein the signal application unit (40) is adapted for applying a plurality of different characteristic stimulus signals (Si) each having a unique feature allowing to unambiguously identify each stimulus signal - or parts thereof - in each received response signal.

20. The system of claim 15 or any one of the claims 16-19, wherein the signal application unit (40) is adapted for applying a plurality of different characteristic stimulus signals (Si) each having a carrier portion and/or an identification portion, with at least one of the carrier portion or the identification portion comprising a unique feature allowing to unambiguously identify each stimulus signal - or parts thereof - in each received response signal.

21. The system of claim 15 or any one of the claims 16-20, wherein the signal application unit (40) is adapted for providing a modulation or coding for generating the plurality of different characteristic stimulus signals (Si).

22. The system of claim 15 or any one of the claims 16-21, wherein the signal application unit (40) is adapted for providing at least some of the plurality of different characteristic stimulus signals (Si) in parallel, preferably concurrently or at least substantially concurrently.

23. A method for determining or verifying a property of an optical device under test - DUT - (10) having m inputs, with m = 1, 2, 3, ..., M, and n outputs, with n = 1, 2, 3, ..., N, comprising the steps of:

(a) receiving a response signal (Ri) at at least one of the n outputs in response to a plurality of different characteristic stimulus signals (Si) applied to at least one of the m inputs, and

(b) determining or verifying a property of the DUT (10) by evaluating the received response signal in conjunction with at least one of the applied stimulus signals (Si) or at least an indication thereof.

24. A method for testing an optical device under test - DUT - (10) having m inputs, with m = 1, 2, 3, ... M, and n outputs, with n = 1, 2, 3, ..., N, comprising the steps of:

(a) applying a plurality of different characteristic stimulus signals (Si) to at least one of the m inputs,

(b) receiving a response signal (Ri) at at least one of the n outputs, and

(c) determining or verifying a property of the DUT (10) by evaluating the received response signal in conjunction with at least one of the applied stimulus signals (Si) or at least an indication thereof.

25. The method of claim 24, wherein in step (a) the plurality of different characteristic stimulus signals (Si) are provided in a way allowing in step (c) tracing each respectively applied stimulus signal (Si) in each received response signal (Ri) - if present or beyond a detectability threshold.

26. The method of claim 24 or 25, wherein step (a) comprises a step of unambiguously modulating or coding each stimulus signals (Si).

27. The method of claim 24 or any one of the claims 25-26, wherein in step (a) at least some of the plurality of different characteristic stimulus signals (Si) are provided in parallel, preferably concurrently or at least substantially concurrently.

28. A method for applying a plurality of different characteristic optical stimulus signals (Si) to at least one input of an optical device under test - DUT - (10) having m inputs, with m = 1, 2, 3, ..., M, and n outputs, with n = 1, 2, 3, ... N, the method comprising the steps of:

(a) applying a plurality of different characteristic stimulus signals (Si) each having a carrier portion and/or an identification portion, with at least one of the carrier portion or the identification portion comprising a unique feature allowing to unambiguously identify each stimulus signal.

29. The method of claim 28, comprising a step of providing a modulation or coding for generating the plurality of different characteristic stimulus signals (Si).

30. The method of claim 28 or 29, comprising a step of providing at least some of the plurality of different

characteristic stimulus signals (Si) in parallel, preferably concurrently or at least substantially concurrently.

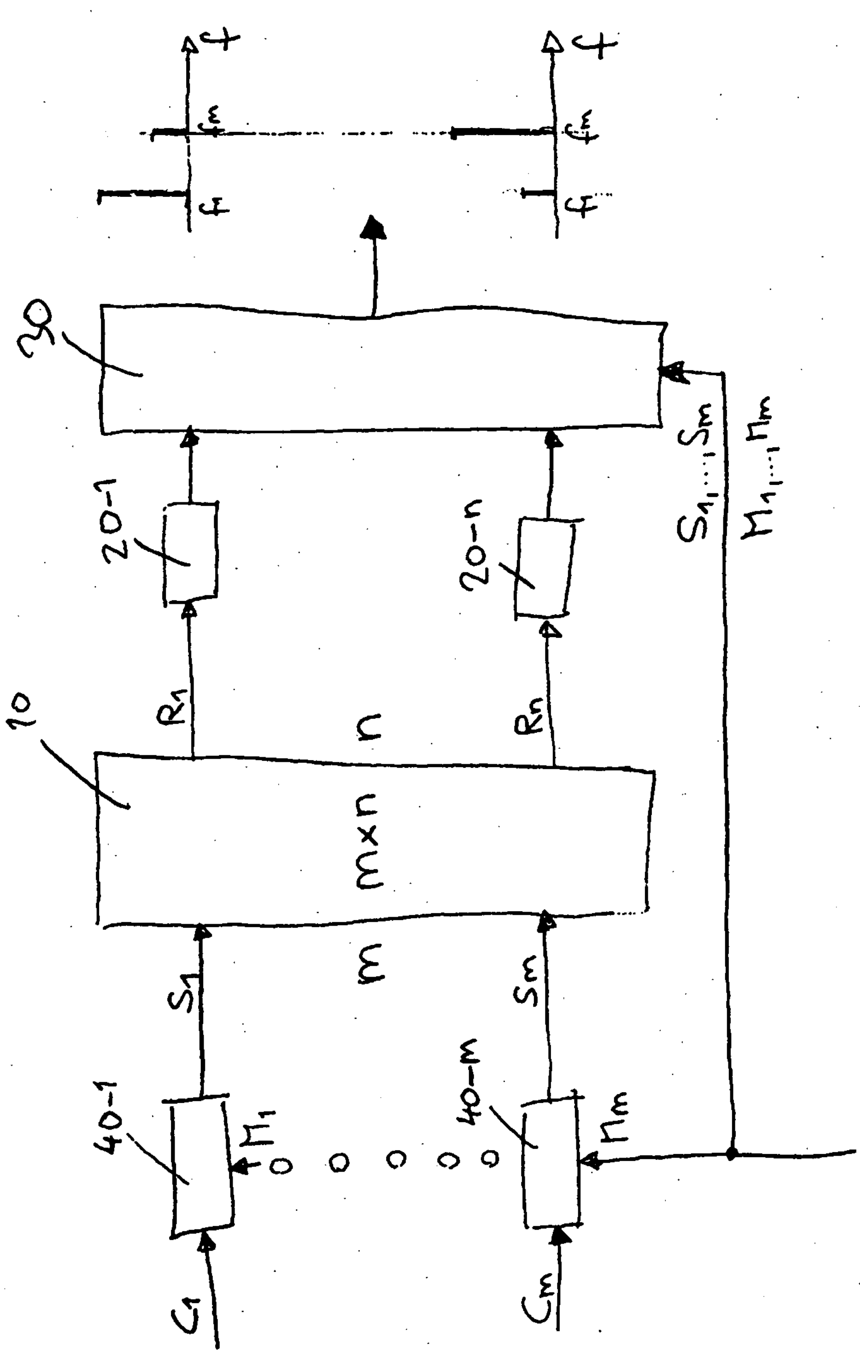

Fig. 1

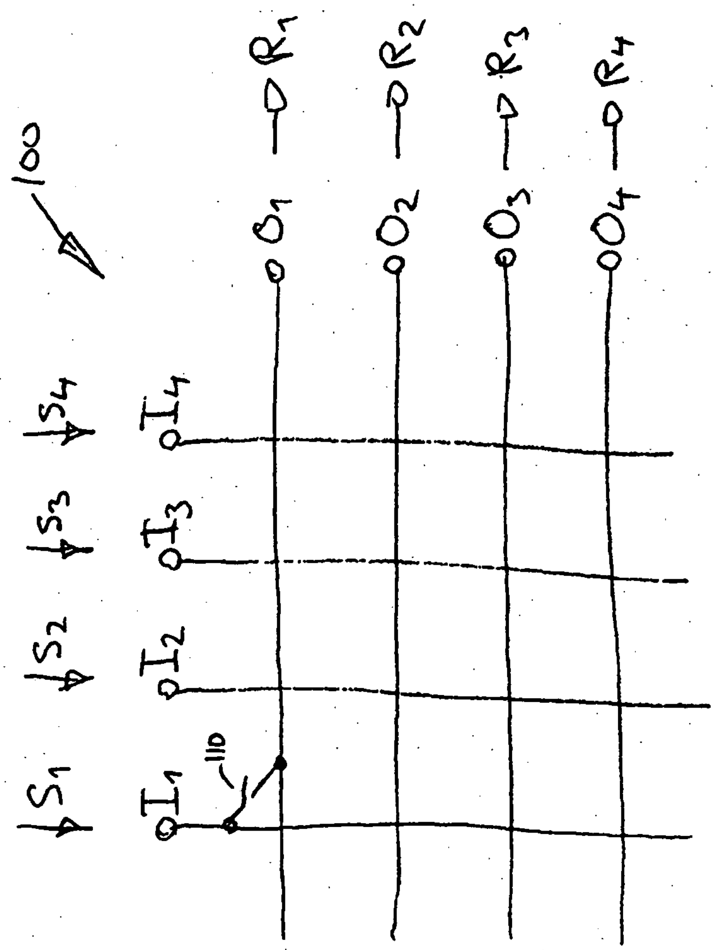

Fig. 2

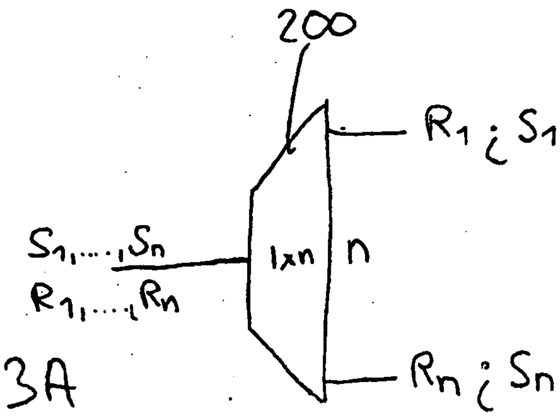
200
R_1 ; S_1
$S_1,\ldots,S_n$
$R_1,\ldots,R_n$
1xn
n
R_n ; S_n

Fig.3A

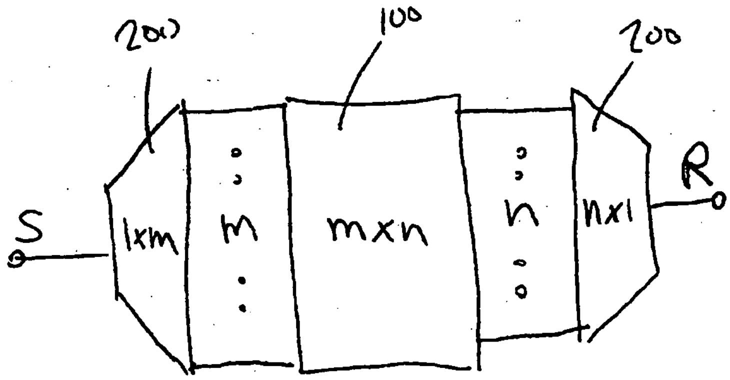
200
100
200
S
1xm
m
mxn
n
nx1
R

Fig.3B

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 01 12 8563

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
A	DE 37 24 334 A (SIEMENS AG) 2 February 1989 (1989-02-02) * claim 1 * -----	1-30	G01M11/00
			TECHNICAL FIELDS SEARCHED (Int.Cl.7)
			G01M

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	29 May 2002	Nobrega, R.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 01 12 8563

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

29-05-2002

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE 3724334 A	02-02-1989	DE 3724334 A1	02-02-1989

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82